11-2008

Progress Toward Meeting the Challenges of our Coastal Urban Future

Juile Pullen
Naval Research Laboratory

Jason Ching
National Oceanic and Atmospheric Administration

David J. Sailor
Portland State University

William Thompson
Naval Research Laboratory

Bob Bornstein
San Jose State University

See next page for additional authors

Citation Details

Pullen, J., Ching, J., Sailor, D. Thompson, W., Bornstein, B. and Koracin, D., "Progress toward the challenges of our coastal urban future", Bulletin of the American Meteorological Society (BAMS), November 2008.

Authors
Juile Pullen, Jason Ching, David J. Sailor, William Thompson, Bob Bornstein, and Darko Koracin

PROGRESS TOWARD MEETING THE CHALLENGES OF OUR COASTAL URBAN FUTURE

BY JULIE PULLEN, JASON CHING, DAVID SAILOR, WILLIAM THOMPSON, BOB BORNSTEIN, AND DARKO KORACIN

Coastal urban regions are a nexus for climate change effects, extreme weather impacts, chemical/biological threats, and air quality issues as the global population increasingly concentrates in cities and megacities at the land–water interface. Sophisticated observational and modeling tools for the coastal urban oceanic and atmospheric domain are emerging to confront these diverse hazards. A coordinated interdisciplinary survey of the applications of these tools to assess past and future changes to the physical environment (air, water, land) surrounding urban centers was a primary goal of our joint coastal–urban conference.

Close integration of the Seventh Conference on Coastal Atmospheric and Oceanic Prediction and Processes and the Seventh Symposium on the Urban Environment was achieved through six joint sessions, four of which were plenary. Morning plenary talks each introduced one of the following daily themes, which were further explored in each conference: *Coastal vulnerabilities, climate change, and urban planning; Advancing our modeling capabilities/tools; Observing and forecasting in the urban-coastal zones; and Modeling for emergency response, dispersion, and air quality in urban-coastal areas.*

A keynote address by the (then) American Meteorological Society (AMS) President-elect Walter Dabberdt urged consideration of the intersection of these themes in an historical perspective. In A.D. 1000, the five largest cities in the world were Cordova (Spain), Kaifeng (China), Constantinople (Turkey), Angkor (Cambodia), and Kyoto (Japan), only one of which was located on the coast. By contrast, in 2015 the five largest cities will all be coastal: Tokyo (Japan), Mumbai (India), Lagos (Nigeria), Dhaka (Bangladesh), and Sao Paulo (Brazil). As this partial

THE SEVENTH CONFERENCE ON COASTAL ATMOSPHERIC AND OCEANIC PREDICTION AND PROCESSES, AND THE SEVENTH SYMPOSIUM ON THE URBAN ENVIRONMENT

WHAT: More than 160 researchers met jointly to survey the state of the science in addressing the challenges faced by the growing coastal and urban centers around the world.
WHEN: 9–13 September 2007
WHERE: San Diego, California

AFFILIATIONS: PULLEN—Naval Research Laboratory, Monterey, California; CHING—ARL, NOAA, Silver Spring, Maryland; SAILOR—Portland State University, Portland, Oregon; THOMPSON—Naval Research Laboratory, Monterey, California; BORNSTEIN—San Jose State University, San Jose, California; KORACIN—Desert Research Institute, Reno, Nevada.
CORRESPONDING AUTHOR: Julie Pullen, Naval Research Laboratory, 7 Grace Hopper Ave., Monterey, CA 93943
E-mail: Julie.pullen@nrlmry.navy.mil

DOI:10.1175/2008BAMS2560.1

In final form 27 May 2008

list suggests, the majority of megacities (70%) are located in less-developed regions of the world, and 78% of them are coastal, creating additional pressures on the population and the environment.

This summary highlights the joint conference session themes, including reflections on key advancements and issues (see the sidebar for information about the special recognition ceremony).

AN EMERGING THEME—THE HETEROGENEITY OF URBAN AREAS. Large cities, such as New York City (NYC; New York) and Tokyo, often possess multiple dense urban cores dictated by geography and history, resulting in highly irregular distributions of building heights and heating footprints. Characterization of this heterogeneity requires tools that measure and model at fine scales. Though intuitively obvious that not all large cities share common urban profiles, tools available in the past often forced a representation of cities as homogeneous. A proliferation of instruments and numerical approaches now afford an unprecedented view of the diversity of urban structures and their influence on the surrounding environment. These tools were showcased at the joint conference, and the capabilities of several are introduced here.

Emerging tools for the measurement of heat fluxes include large-aperture scintillometry, which captures the areal measurements at scales larger than traditional sonic anemometers. A new satellite hyperspectral sensor (Operative Modular Imaging Spectrometer, with 128 spectral bands) measures urban surface radiative characteristics, including emissivity and albedo, rarely available at high spatial resolution, and provides insight into the ability of standard satellite-based sensors to estimate urban heat fluxes.

Mobile probes driven through the streets of cities such as Houston, Texas, and Portland, Oregon, are yielding refined near-surface canopy air temperature urban heat island maps. In daytime, a horizontal displacement of the largest heat values occurs due to shading from tall buildings. These 2D maps can yield insight into the relative importance of various factors contributing to the urban heat island and provide useful validation data for radiative measurements of urban surfaces from remote platforms.

Many cities experience sea breezes, which alter the urban energy balance and impact the transport and dispersion of airborne contaminants, as the time-varying winds move among urban structures. For example, a recently developed sea-breeze index that is based on surface heating was applied to five cities with urban energy balance flux measurements (Chicago, Illinois; Los Angeles, California; Marseilles, France; Miami, Florida; and Vancouver, British Columbia, Canada) to catalog the occurrence of sea-breeze events. When the surroundings were heterogeneous, pronounced differences in flux partitioning on sea-breeze versus non-sea-breeze days occurred.

National Urban Database and Access Portal Tools (NUDAPT) is a prototype database of heterogeneous urban parameter fields designed specifically for the urban environmental modeling community. The impetus for NUDAPT arose from 1) the advent of advanced model parameterizations that describe the urban boundary layer, and 2) expanding 3D databases of high-resolution building and urban morphological data from new sensor technologies. NUDAPT is concluding a pilot research and development project sponsored by the U.S. Environmental Protection Agency that involves State, Federal (civilian and defense), and Canadian agencies, universities, and the private sector. Initial implementation is a community-based, Web-based portal technology system with multiple datasets that include high-resolution building data from lidar measurements on airborne platforms, as well as derived and gridded model parameters (including tools for their creation, regridding, and reprojection). The prototype also includes gridded daytime and nighttime population data for exposure assessment, as well as anthropogenic heating rates for improved boundary layer modeling, both at 250-m resolution. Urbanized meteorological and air quality model sensitivity studies for

SPECIAL RECOGNITION CEREMONY

The inaugural AMS Helmut Landsberg Award for Urban Meteorology was presented to Professor Tim Oke of the University of British Columbia. This award recognizes an individual or team for exemplary contributions to the field of urban meteorology, climatology, or hydrology. Paraphrasing from the citation, Prof. Oke has received the award for his visionary leadership in urban climatology and meteorology and for his numerous, seminal, and lasting contributions to the science over four decades, as reflected by substantive and enlightening publications and through the mentoring of many young scientists currently engaged in urban research. In addition, Julie Pullen, Chair of the Coastal Environment Committee, presented a Certificate of Appreciation to Professor Mariano A. Estoque of the Manila Observatory, Quezon City, Philippines, in recognition of his fundamental and ongoing contributions to planetary boundary layer and sea-breeze modeling.

Houston and Sacramento, California use refined spatially gridded NUDAPT data to identify places within the city where adjustments to key parameters, such as anthropogenic heating and emissions, would translate into reductions in the heat island and ozone concentrations.

Data from these new tools and databases must be updated in a timely manner to capture the temporal evolution of cities and their imprint, especially in light of the expected emergence of new megacities in coastal areas.

COASTAL VULNERABILITIES, CLIMATE CHANGE, AND URBAN PLANNING. Predicting climate change impacts on urban areas requires a robust framework that can be used to evaluate and compare predictions for global cities. Such a framework should encompass an international synthesis of urban impact tools, including high-resolution urbanized models, and scenarios to assist in mitigating vulnerabilities to sea level rise and extreme events. For example, one recent study used output from 14 global climate models (GCMs) to generate probabilities of extreme events for NYC on a 9-km resolution grid. The simulations predicted that the frequency of high heat days, for example, would increase fourfold by 2050 and sevenfold by 2080. Such predictions are attended by questions regarding the readiness of the science to meet worldwide stakeholder demands at urban scales. Better communication of risk time scales, prediction uncertainties, and recurrence intervals is needed in the face of extreme events like the 8 August 2007 flooding in NYC, which shut down the transportation network.

Increasing damage to urban areas by hurricanes and the potential long-term change in hurricane activity related to climate change are both issues that require better science and more sophisticated mitigation and adaptation approaches. While hurricane track forecasting has improved in recent years, negligible improvement in hurricane intensity forecasting has occurred in the past 15 yr. Progress in hurricane intensity forecasting will come with improved knowledge and high-resolution modeling of inner-core (eye and eyewall) dynamics and air–sea interaction in extreme wind conditions. For instance, aircraft measurements revealed that the intensity of Hurricane Rita (2005) had reduced prior to landfall because of an eyewall replacement hours earlier. Proper representation is needed of two competing processes in hurricane intensification/decay at the air–sea interface: the heat and moisture fluxes that fuel the storm and the dissipation of kinetic energy at the ocean surface. This requires linked air, sea, and land models because surface properties, such as ocean wave state, sea surface temperature (SST), and even urban morphology, can influence the energy balance that sustains and drives hurricanes.

ADVANCING OUR MODELING CAPABILITIES/TOOLS. Motivated by air quality issues, urban climate concerns, and weather forecasting needs, improvements to urban canopy parameterizations within mesoscale models have progressed swiftly over the past 10 yr to account for increasingly complex aspects of urban environments. These parameterization schemes build geometry, orientation, and reflective properties into models to provide an improved representation of the albedo, drag, and radiation of urban surfaces.

A novel mesoscale ensemble modeling study employed several urban canopy schemes with perturbations of fundamental urban parameters, such as building height and anthropogenic heating. In addition to supplying information on which urban factors account for the most uncertainty (and thus providing a means to rationally prioritize data collection efforts), this approach could produce more robust forecasts, provided operational computing resources can accommodate the increased model grid resolution and processor requirements.

The benefits of utilizing SST from in situ sensors, satellites, or high-resolution ocean models in meteorological mesoscale models are numerous. In one example, improved realism (including internal boundary layer formation) and skill was attained by supplying hourly ocean model SST as input to a 0.4-km-resolution urbanized meteorological simulation of NYC. Also, specification of SSTs measured at moorings in Tokyo Bay for a 1-km-resolution semi-urbanized mesoscale model likewise led to better agreement with observed heat flux.

Computational fluid dynamics (CFD) models are powerful tools for resolving small-scale transport including flow around individual buildings. Though computationally demanding, CFD models have a myriad of uses in urban dispersion, source inversion, and instrument-siting studies. CFD models are now being used to improve bulk urban canopy methods in mesoscale models, and reciprocally, mesoscale models can be used to initialize CFD models. A prime example is the multiscale simulations underway at the Earth Simulator center in Yokohama, Japan, which employ 2-km resolution for the global atmosphere and achieve 3-km resolution for the Pacific Ocean. Embedded in the coupled model is a CFD model of

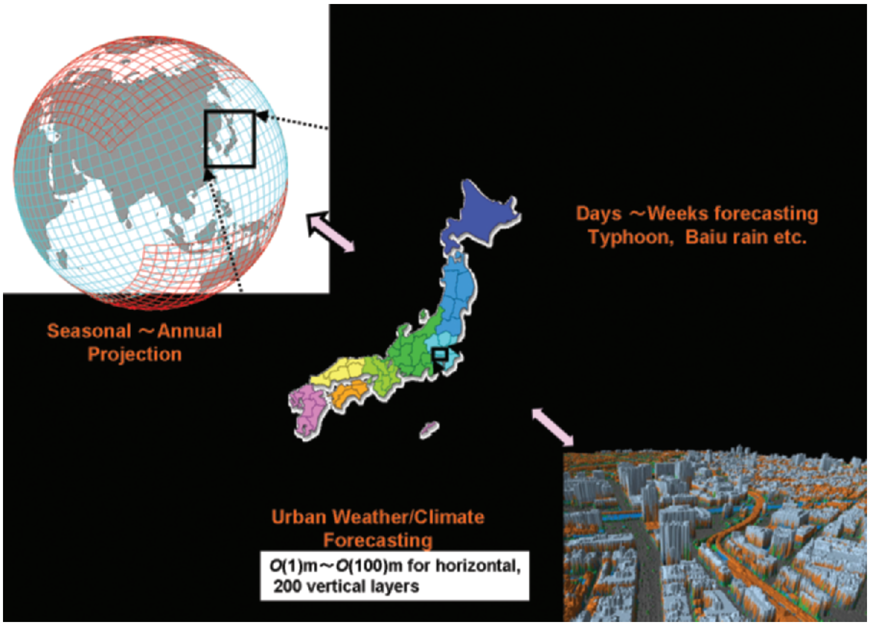

Fig. 1. Schematic of multiscale modeling, from global to urban scales, for weather and climate applications (courtesy of Dr. Keiko Takahashi). Urban building data were provided by the Geographical Survey Institute, Japan.

sublayer), which are representative of the local or neighborhood scale.

Over the past decade, ocean measurement platforms have undergone a transformation. Local networks of autonomous underwater vehicles, gliders, and radars are increasingly being deployed to monitor the environment, while nested high-resolution data-assimilating ocean and atmosphere models provide predictions at fine scales. Powerful systems are under development to unite these technologies as the backbone of the U.S. Coastal Ocean Observing System. For example, the New York Harbor Observing and Prediction System (NYHOPS) synthesizes data from moorings, gliders, ferries, and a forecast ocean model to monitor and predict estuary and coastal circulation in the harbor. The system is utilized by emergency response, the coast guard, and ferry operators for water contamination and coastal flooding forecasts as well as safe vessel navigation through the port, and serves as a flagship for multiuse, self-sustaining, integrated observing and modeling in an urban coastal zone.

central Tokyo with 5-m-resolution building geometry (Fig. 1). Such integrated modeling has a high potential payoff for urban climate, weather, and chemical/biological applications.

OBSERVING AND FORECASTING IN THE URBAN–COASTAL ZONE. Numerous urban meteorological measurement campaigns have been conducted in coastal cities, including in the developing world, but few represent long-term, ongoing data collection programs. The structure and evolution of turbulence in the urban environment is highly dynamic and sensitive to wind direction, stability, synoptic conditions, and building and vegetation coverage. Thus, along with temporal limitations of the data, instrument siting in locations that are representative of the surroundings remains a challenge. To address this problem, the importance of scale when making, analyzing, and interpreting urban measurements was stressed (Fig. 2). Flows within the urban canopy layer (UCL) and roughness sublayer (microscale) should be differentiated from those in the blended flow regimes (inertial

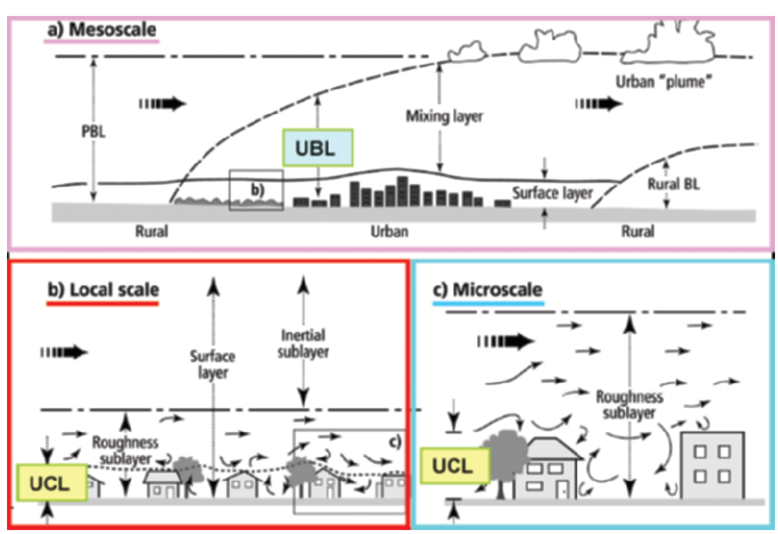

Fig. 2. Urban boundary layer (UBL) processes from the mesoscale to microscale (courtesy of Sue Grimmond).

On the U.S. west coast, operational ocean forecasts have been used to successfully guide search and rescue missions, and have demonstrated the value gained by assimilating radar-derived ocean surface currents into numerical models. Intensive observing programs, such as the Autonomous Ocean Sampling Network (AOSN) and Adaptive Sampling and Prediction (ASAP) projects that both took place recently in Monterey Bay, are demonstration test beds for new technologies and concepts. They include innovative modeling approaches that link ecosystem and optics prediction with high-resolution ocean circulation models.

MODELING FOR EMERGENCY RESPONSE, DISPERSION, AND AIR QUALITY IN URBAN–COASTAL AREAS. Fast-response models are deployed for emergency chemical/biological releases and they rely on techniques for the representation of building influences on winds, without direct simulation of flows around the buildings. Data from two urban dispersion field studies in NYC in 2005 (Midtown and Madison Square Garden) reveal sensitivities of tracer distributions to sea breeze and surface heating interactions at building scales and are spurring improvements in CFD and fast-response models through model intercomparison exercises. Tracer motion can also be studied by the construction of model cities in wind tunnels. Analyses of such models reveal vastly different turbulence footprints spawned by flow over flat versus slanted roofs, and are providing insights for numerical models.

For regulatory purposes, multiscale and multipollutant models will be needed for future air quality management requirements and to facilitate more robust assessments of environmental impacts, particularly in urban coastal areas. Given the dependence of such models on the parametrized details of chemical interactions in the atmosphere, uncertainty estimates are essential.

CONCLUSIONS. Projections of rapid urban growth impart urgency to a joint coastal–urban research agenda. Our communities are poised with advanced modeling and observing tools that account for the heterogeneous nature of urban coastal areas. These tools and approaches invite synthesis. From a forecasting perspective, deployment of high-resolution, coupled ocean and atmosphere, urbanized data-assimilating models could supply critical information for multiple uses. Multiscale modeling that includes a CFD building-resolving capability (receiving boundary information from the larger scale) holds promise for assessing and responding to specific threats to coastal cities.

Despite these improvements, the combined conferences highlighted the need for integrated studies of urban coastal realms to provide robust answers to pressing challenges, such as the following:

1) What will be the impact in time and space of climate change on local urban scales, and how can predictions and uncertainties be communicated in targeted ways?
2) How can forecasting systems help improve the resilience of urban and coastal areas (including building structures and ecosystems) in the face of extreme events?
3) How does urban heterogeneity impact contaminant dispersion?
4) How can urban air quality mitigation strategies be tailored to specific localities?

These and other significant questions are being addressed with ongoing research, and will be discussed in greater detail in the Eighth Conferences on Coastal Atmospheric and Oceanic Prediction and Processes, and the Urban Environment at the AMS Annual Meeting in Phoenix in 2009.

ACKNOWLEDGMENTS. We thank John Lewis, James Voogt, Aurore Porson, and Alberto Martilli for contributing reports of the sessions they chaired. Thanks also to Sue Grimmond and John Kindle for providing comments on the draft of this summary. The genesis of the joint conference was a special symposium, "Nexus of Coastal and Urban Environments," organized by Chris Mooers at the 2004 AMS annual meeting in Seattle. Finally, we thank all conference participants for making the Seventh Conference on Coastal Atmospheric and Oceanic Prediction and Processes and the Seventh Symposium on the Urban Environment a stimulating event. Photos from the conference can be viewed online (www.fuse.pdx.edu/7thcoastalurban.htm).